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Comprehensive Application of Computational Geometry Technology and Conservation Renovation in Wind Environment Adjustment of Traditional Residential Buildings

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Abstract: - In this paper, the wind environment adjustment problem of traditional residential buildings is deeply studied by integrating the computational geometry technology and the protective remodeling strategy. Through the computational fluid dynamics software CFX, combined with the SST k-ω turbulence physical model and unstructured grid technology, numerical simulations are carried out for the circular, square and heliostat buildings in traditional residential buildings. Based on BIM and building code standards, a reliability evaluation method based on residents' comfort under building wind environment is established. Numerical simulations show that the wind pressure coefficient reaches its maximum value at a height of about 3 m for both round and square residential buildings, and the lowest wind pressure coefficient is -1.47 at the gap of the building.For the day-shaped residential buildings, the wind speed in the interior site is relatively low, especially at the height of the pedestrians, and the average wind speed is only 0.34.The percentage of the wind environment at the exterior measurement points is low in the warm season for the round, square, and day-shaped residential buildings, and the percentage of the wind environment at the exterior measurement points is low in the warm season. The percentage of wind environment was low for round, square, and day-shaped residential buildings, 5.1%, 4.9%, and 4.4%, respectively, and high for cold season exterior measurement points, 34.3%, 35.6%, and 34.4%, respectively. Strategies for the conservation and renovation of residential buildings are formulated, including optimization of the design of the external environment and ventilation of the building, optimization of the design of the building structure that guides the natural ventilation, and mechanically-assisted enhanced ventilation design.

Keywords: Traditional residential buildings; Environmental adjustment; Computational geometry technology; Conservation renovation; Fluid dynamics

1. INTRODUCTION

With the rapid advancement of urbanization, traditional residential buildings, as an important carrier of history and culture, carry a wealth of regional characteristics and ethnic customs [1-2]. As an important part of cultural heritage, the protection and renovation of traditional residential buildings have received extensive attention from all walks of life [3]. However, with the change of the times under the impact of modern living needs, many traditional houses are facing problems such as poor wind environment, which is difficult to meet the living comfort and health needs of modern people. Therefore, how to scientifically and reasonably adjust the wind environment of traditional houses, and at the same time protect and inherit the cultural heritage of the traditional residents' built environment, as well as improve the living quality of its residents, has become an important issue in the field of adjusting traditional houses at present [4-5].

As an important branch in the cross field of modern computer science and mathematics, computational

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geometry technology, with its powerful data processing and graphical analysis capabilities, provides strong technical support for engineering design, building simulation and other fields, and at the same time, it is able to realize the accurate assessment and effective adjustment of the wind environment of buildings. In recent years, more and more scholars have made in-depth analysis in the field of architecture, especially in the adjustment of the wind environment of the building, analyzing the distribution of the airflow field and the change of the wind speed around the building through numerical simulation methods, and have achieved remarkable research results. Wang, R. et al. compared the effects of typical Chinese climates in terms of uncertainty and sensitivity analyses and used finite element analysis to explore the effects of window openings for ventilation and shading on the performance of the building design to inform the retrofit measures in this paper [6]. Paul, R et al. performed numerical simulations using ANSYS-CFX finite element analysis software with length and velocity scales of 1:300 and 1:5 respectively. Surface streamlines were proposed to characterize the wind flow and envisioned the regions and nature of flow separation and vortex generation for the design of building cladding [7]. Jafari, M evaluates the wind direction, building shape, height and wind vibration of Gundeng buildings through computational fluid dynamics to enhance the effectiveness and generalization of building design [8]. Zhang, M et al. In Computational Fluid Dynamics simulation of wind environment using Phoenics software, focusing on the field measurements of the local wind environment of the approach bridge of a suspension bridge in mountainous area including the changes of parameters such as wind speed, wind direction and wind pressure at different locations and time. And a new method based on the wind parameter analysis of large-span suspension bridges in mountainous areas is proposed to investigate the relationship between the incoming flow and the wind characteristics of the bridge deck. The calculation results show that the local wind environment on the bridge deck is significantly different from the incoming flow characteristics [9].

Computational geometry techniques also play an important role in the optimal design of buildings, where the optimization of building geometry can be adjusted to improve the ventilation performance of the building and enhance occupant comfort. For example, Gimenez, J. M et al. proposed a simulation-based optimization method to improve the prediction of the mean pressure coefficients of building wind surfaces by calibrating the Reynolds mean coefficients. The validation found that the model error seen was minimized [10]. Jafari, M et al. developed a numerical simulation and statistical analysis overview framework to simulate a two-dimensional scale model using fluid dynamics. Based on response surfaces, the wind and load and response of high-rise buildings were evaluated [11]. Zhao, Q. used a microscale computational fluid dynamics flow model to finely simulate the diffusion process of wind flow field in a park. A significant negative correlation between wind speed and pollutant levels in the park was derived. The higher the wind speed, the higher the air quality. At the same time, the coverage and enclosure of the building complex are significantly negatively correlated with the wind speed conditions. By adjusting the spatial layout parameters such as coverage, enclosure and average height of the building complex, the wind environment and air quality in the park can be significantly improved [12]. Juan, Y. H et al. used computational fluid dynamics tools to analyze the urban wind energy potential, and the results concluded that rounded corners have higher power densities than acute corners, and rounded corners have greater wind energy potential [13].

Computational geometry technology in the adjustment of architectural wind environment not only helps to improve the scientific and accuracy of architectural design, but also provides strong support for the living comfort of residential houses. Combined with the previous research results, this paper gathers with the research on the comprehensive application of computational geometry technology and the wind environment adjustment of traditional residential buildings with protective remodeling. Based on the computational fluid dynamics soft CFX, the SSTk-ω turbulence physical model and unstructured mesh, wind angle setting, boundary conditions and turbulence model, etc., a cladding refinement mesh is used within a certain height from the ground, and numerical simulation is carried out on the circular residential buildings, square residential buildings and day-shaped residential buildings in Lijiang residential buildings by using the mixed windward format and different wind angles. A series of conservation and renovation strategies are designed, including the design of external environment and ventilation, the optimization of building structure to guide natural ventilation, the design of mechanically-assisted enhanced ventilation, and the micro-renewal strategy of traditional residential buildings under the optimization of the wind environment, which provide scientific basis and technical support for the conservation and renovation of traditional residential buildings.

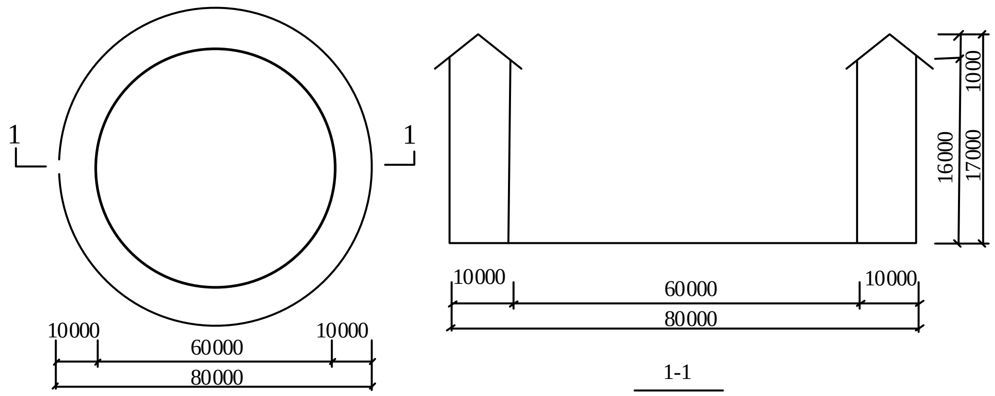
2. COMPUTATIONAL GEOMETRY TECHNIQUES AND SPECIFIC APPLICATIONS IN WIND ENVIRONMENT SIMULATION

2.1 Model meshing and wind angle setting

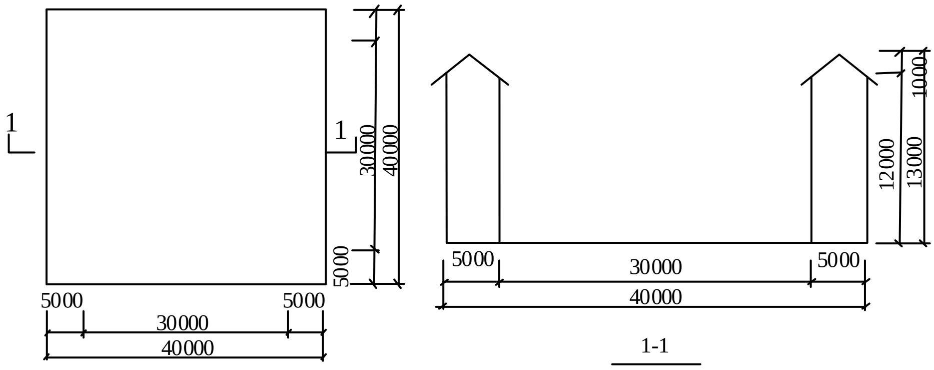
Due to China's vast territory, many nationalities, different geographical and climatic conditions and lifestyles in different places, the traditional residential buildings are diversified in styles and manners. In this paper, representative traditional residential buildings in Lijiang with 1-3 floors are selected, and traditional round residential buildings and traditional square residential buildings are the most common, and this paper selects traditional round residential buildings, traditional square residential buildings and traditional day-shaped residential buildings as models.

2.1.1 Introduction to the model

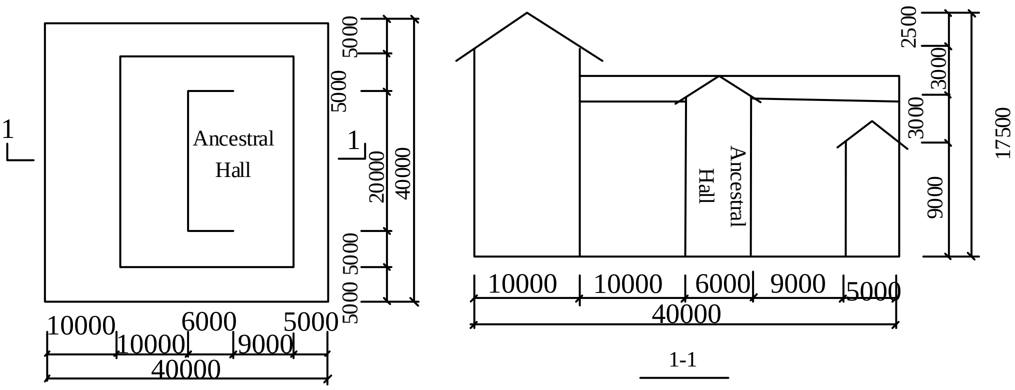
Fig. 1 is the geometric model of the traditional residential building, the traditional circular residential building is shown in Fig. 1 (a), the outer diameter D=80m, the inner diameter d=60m, the eaves height h=16m, the ratio D:d:h=1:0.75:0.2, and the roof slope is 1:5. As shown in Figure 1(b), the traditional square residential building has an outer length of L=40m, an inner length of L=30m, an eaves height of h=12m, a ratio of L:l:h=1:0.75:0.3, and a roof slope of 1:2.5. Figure 1(c) shows the model of the central hall of a traditional Japanese-shaped residential building, with the outer length L=40m and the inner length L=40m.



(a) Traditional round residential buildings



(b) Traditional square residential buildings



(c) Traditional Japanese-style residential buildings

Figure 1 Geometric model of traditional residential building

2.1.2 Grid division

The computational fluid dynamics software CFX is used to calculate and establish the numerical model according to the above dimensions, and the center of the model is located in the long axis of the bottom surface of the numerical wind tunnel 1/3 from the entrance of the wind tunnel, and the dimensions of the numerical wind tunnel, the total number of grids, and the blockage rate are shown in Table 1. The numerical wind tunnel of the circular residential building has the largest size, 1200x500x160m, and the largest number of grids, 1,123,000, but its blockage rate is relatively low, 1.9% [14]. The numerical wind tunnel dimensions of the square residential building and the day-shaped residential building are the same, and the number of grids of the square residential building is 882,000 with a blockage rate of 1.8%. While the day-shaped residential building but its grid number is the least, 696,000, the obstruction rate is the highest of the three, 2.2%, these data provide the data basis for the boundary conditions and turbulence modeling.

Table 1 Numerical wind tunnel dimensions, number of grids, blockage rate

Model	**Numerical Wind Tunnel Dimensions LxWxH/m**	**Number of grids / 10,000**	**Obstruction rate**
Round residential buildings	1200x500x160	112.3	1.9%
Square Residential Building	800x400x120	88.2	1.8%
Day-shaped residential buildings	800 x400x120	69.6	2.2%

In order to accurately get the wind field near the building, the key problem is to simulate the ground turbulence as well as the flow situation near the building, therefore, this paper adopts the adaptable unstructured mesh while encrypting the mesh on the solid ground, the surface of the building in order to get the more precise mesh, the encrypted thickness is H :

$$H = \sum_{i=1}^{n} h_1 q^{i-1} \quad (1)$$

Where: h_1 is the thickness of the first prismatic mesh layer, $m:q$ is the rate of change of thickness, and n is the number of layers. The four models in the paper use $h_1 = 0.2\text{m}$, $q = 1.2$, and $n = 6$. As follows:

$$H = \sum_{i=1}^{n} h_1 q^{i-1} \quad (2)$$

2.1.3 Wind angle

The wind angle of residential buildings is shown in Fig. 2, and the traditional circular residential buildings and double-ring residential buildings are center-symmetric, and the wind angle is only taken as 0°. The wind direction angles of traditional square residential buildings are 0°, 15°, 30°, 45°, and the wind direction angles of traditional day-shaped residential buildings are 0°, 30°, 60°, 90°, 120°, 150°, 180°. Ninety-four measurement points were arranged at a height of 2m and 1.5m from the inner wall with a spacing of 1m, and the serial numbers of the measurement points were arranged counterclockwise [15].

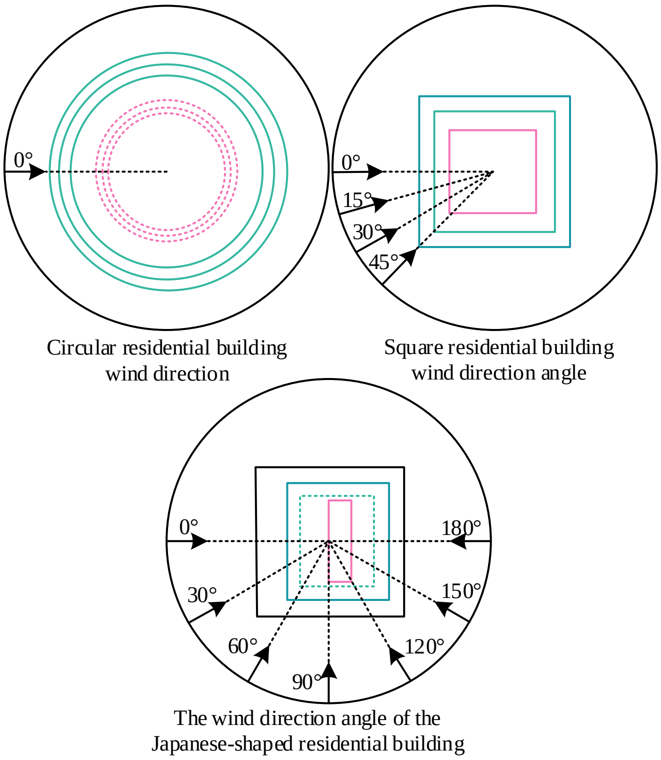


Figure 2 Wind angle of residential buildings

2.2 Boundary conditions and turbulence modeling

2.2.1 Boundary conditions

Inlet wind profile:

$$u_1 = u_0 \left(z / z_0 \right)^{\alpha} \tag{3}$$

Turbulence intensity:

$$I(z) = \begin{cases} 0.23 & z \leq 5\mathrm{m} \\ 0.1 \times \left(\dfrac{z}{z_G} \right)^{-\alpha - 0.05} & 5\mathrm{m} < z \leq z_G \end{cases} \tag{4}$$

Where: u_1 is the horizontal wind speed at vertical height z, u_0 is the wind speed at reference height z_0, this paper takes $z_0 = 1m$, $u_0 = 6.918m/s$. The ground roughness where the residential building is located is class B, and the roughness coefficient α is taken as 0.16, $z_G = 350m$.

Turbulent kinetic energy:

$$k_1 = 1.2\left(Iu_1\right)^2 \quad (5)$$

Turbulence Integral Scale:

$$L = 100(z/30)^{0.5} \quad (6)$$

Dissipation rate:

$$e_1 = \left(k_1^{1.5}C^{0.75}\right)/(K \cdot L) \quad (7)$$

Where, z is the height of the traditional residential building, constant $C = 0.09$ Karman's constant $K = 0.41$, turbulent kinetic energy k_1, and turbulence integral scale L are determined by equations (4) and (5), respectively. It is assumed that the turbulence at the exit is fully developed and the static pressure is 0 [16-17]. Non-slip wall surfaces are used for the ground and traditional residential building surfaces, and the wall function method is used in the near-wall region. The numerical wind tunnel boundaries were used as free-slip wall surfaces.

2.2.2 Turbulence modeling

In the simulation process, in order to more accurately simulate the turbulence behavior in traditional residential buildings, including traditional circular residential buildings, traditional square residential buildings, and traditional day-shaped residential buildings are selected as models. In this paper, the SSTk-ω turbulence physical model is adopted and combined with the 1.75-order windward format for numerical simulation. In the simulation process, different wind angles are set and detailed numerical simulations are carried out for traditional round residential buildings, traditional square residential buildings and traditional sun-shaped residential buildings. Meanwhile, the coupling of pressure and velocity is adopted by SIMPLE algorithm and realized by staggered grid technique. When the iterative residuals are less than 0.0001, it indicates that the calculation has converged, thus ensuring the accuracy and reliability of the simulation results. This improved model and methodology enable to capture and predict the simulation results more accurately and can understand the wind environment characteristics of traditional residential buildings [18].

3. RELIABILITY ANALYSIS METHOD FOR WIND ENVIRONMENT COMFORT

3.1 Design standard value of wind speed for building environment

For simplicity, notation v_d is the comfort wind speed considered in building design. The design value of v_d can be obtained by using theoretical analysis, experimental research, design experience and personnel living experience and other factors to consider comprehensively and refer to national standards or codes. The control range of Definition v_d is $\Omega = \{v' < v_d < v''\}$ (where v' and v'' are the lower and upper limits of the design wind speed control indexes, respectively).

3.2 Actual wind speed

Set v_r is the actual wind speed on site, which is usually obtained by testing methods, or its approximation can be obtained by using wind tunnel simulation techniques and numerical simulation methods [19]. v_r is actually related to the environmental conditions of the building area, building layout, residential building spacing, residential building height, residential building volume ratio, comfort, and other factors.

3.3 Comfort-based reliability calculation methods

The reliability of comfort in a building park is defined as v_r the likelihood of controlling within the design value, $v_r < v_d$ which can be expressed as the probability of occurrence of an $v_r < v_d$ event:

$$P_s = P_s(v_r < v_d) \tag{8}$$

According to the theory of reliability evaluation, the corresponding calculated value of the comfort reliability of occupancy of people under wind loads at a certain period of time in a design park determined according to the design value, P is called the comfort reliability. Comfort reliability reflects the likelihood that actual comfort will be generated during the actual operational phase of the building, and is a more comprehensive interpretation of the deterministic design evaluation methodology, taking into account, in particular, the uncertain nature of the wind environment.

The calculations depend on the pattern of probability distribution of random variables v_r & v_d. If the density function of the probability distribution of v_r & v_d is $f\left(q_r, q_d\right)$, the formula is as follows:

$$P = P(v_r < v_d) = \iint_{v_r < v_d} f\left(v_r, v_d\right) dv_r dv_d \tag{9}$$

Assume that v_r and v_d are independent of each other and that $f\left(v_r\right)$ and $f\left(v_d\right)$ are the density functions of the probability distributions of v_r and v_d, respectively, which can be rewritten as:

$$P(v_r < v_d) = \int_0^{\infty}\left[\int_0^{v_d} f\left(v_r\right) f\left(v_d\right) dv_r\right] dv_d = \int_0^{\infty} f\left(v_d\right)\left[\int_0^{v_d} f\left(v_r\right) dv_r\right] dv_d \tag{10}$$

When v_r and v_d are normally distributed, define $Z = v_r - v_d$, then Z obeys a normal distribution,

$N\left(\mu_Z,\sigma_Z^2\right)$, $Z=v_r-v_d<0$ are comfort reliability events that meet the requirements of the design code. The comfort reliability probability of wind environment in the building park is:

$$P_s=P(v_r<v_d)=P(v_r-v_d<0)=P(Z<0)=\int_{-\infty}^{0}f(z)\mathrm{dz}=\left(1/\left(\sqrt{2\pi}\sigma_Z\right)\right).\int_{-\infty}^{0}\left\{\exp\left[\left(z-\mu_Z\right)^2/\left(2\sigma_Z^2\right)\right]\right\}\mathrm{dz} \quad (11)$$

Let $t=\left[z-\mu_Z\right]/\sigma_Z$, β be denoted as reliability indicators, then:

$$P_s=(1/\sqrt{2\pi})\int_{-\infty}^{\frac{-\mu_Z}{\sigma_Z}}\left[\exp\left(t^2/2\right)\right]dz=\Phi\left(-\mu_Z/\sigma_Z\right) \quad (12)$$

$$\beta=\left(\mu_{v_r}-\mu_{v_d}\right)/\sqrt{\sigma_{v_r}^2+\sigma_{v_d}^2} \quad (13)$$

Where: $\Phi(\cdot)$ is the standard normal distribution function, β is the reliability index, μ_{v_r} and σ_{v_r} are the mean and standard deviation of wind speed v_r, and μ_{v_d} and σ_{v_d} are the mean and standard deviation of wind speed v_d.

4. DEVELOPMENT AND IMPLEMENTATION OF CONSERVATION REHABILITATION STRATEGIES

4.1 Exterior Building Environment and Ventilation Design

4.1.1 Greening for wind guidance

To address the wind environment problem in the cold season, additional wind-blocking facilities, such as wind-blocking walls and plant barriers, can be installed around residential buildings to minimize the impact of strong winds on pedestrians, and Figure 3 shows the outdoor to wind environment protection of residential buildings. In particular, square residential buildings need to strengthen the installation of wind-blocking facilities because the number and percentage of measurement points with R>1.5 outside their buildings are the highest. At the same time, a suitable layout of green belts can also promote air convection because a temperature difference is formed between a large area of greenery and the surrounding open space with no greenery, and under static wind conditions, this temperature difference can generate a gradient in air pressure, creating local spatial convection and generating breezes. In addition, according to the different wind directions in winter and summer, trees or shrubs are planted in different directions of residential buildings to effectively guide the wind direction and reduce the negative pressure impact on the leeward side and flanks, thus further enhancing the comfort of the residents' living environment.

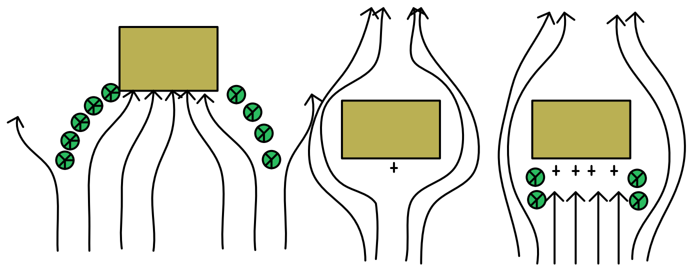


Figure 3 Residential building outdoor to wind environmental protection

4.1.2 Enhanced ventilation using water bodies

Water is a large heat storage material, water evaporation can take away a lot of heat and thus significantly reduce the air temperature around the water body. And the specific heat of water, water temperature annual change is small, is conducive to stabilize the outdoor temperature in winter. Residential courtyard can be appropriate to use a larger water body area, to enhance its effect of improving the environment. The water body should be arranged in the wind direction, which can play a role in cooling the summer hot wind, living near the water can be warm in winter and cool in summer.

4.2 Optimized design of building structure to guide natural ventilation

4.2.1 Building plan ventilation optimization

In order to optimize the wind environment inside residential buildings during the warm season, which is relatively weak, additional doorways and optimized window designs can be considered to improve ventilation in order to promote natural ventilation and cooling. Figure 4 shows the roof and chimney ventilation modification in residential buildings to improve the wind speed and comfort inside the building. Especially in residential building types with high measurement points in the building, such as square residential buildings, the optimization of the internal wind environment needs to be focused on. The building space form has a great relationship with the indoor ventilation environment, through the adjustment of the building space form can significantly improve and guide the natural ventilation thus improving the indoor air quality. From the point of view of the monolithic form of doors and windows, there are more types of doors and windows in traditional village houses, and the common doors in traditional houses can be divided into two types: panel doors and lattice doors. Among them, the ventilation and air permeability of the panel door is poorer than that of the lattice door, and the ventilation and air permeability is strengthened by setting up the openable "bright son" on the upper part of the panel door. From the perspective of the combination of windows and doors, the indoor space generated by the different separations of windows and doors has a great impact on the wind speed, and the traditional residential houses usually have smaller window sizes due to the structural limitations and depth dimensions, so the windows and doors can be combined with the roof or chimneys to strengthen the natural ventilation of the indoors.

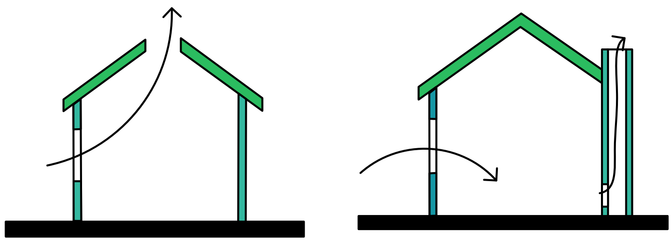


Figure 4 Roof and Chimney Ventilation Retrofit in Residential Buildings

4.2.2 Optimization of building roof ventilation

The roofs of many traditional houses in Lijiang area are in the form of cold spread tiles, which are not adaptable to the continuous high temperature in summer in Lijiang, and can be optimized through the roof itself or through the roof attic, etc. The optimization of the roof itself is mainly realized through the roof air layer. For the optimization of the roof itself, it is mainly realized through the air layer of the roof, on the one hand, using the air layer between the tile surface and the wooden planks to avoid the direct sunlight radiation into the room, and on the other hand, through the internal air layer of the heat pressure and wind pressure to ventilate the room.

4.2.3 Localized reinforcement to avoid eddy currents

For round and square dwellings, considering that the wind pressure coefficient reaches its maximum value at a height of about 3 meters, it is considered that in this height area, a reinforced structural design is carried out to pass the wind resistance of the building. At the same time, traditional residential buildings tend to form vortex zones between residential buildings due to the close spacing of the buildings, which is not conducive to air pollution emissions. Some buildings can be moderately reconstructed when conditions permit, so that the main wind corridor under the dominant wind direction can spread into the residential interiors, and moderate wind alleys through the houses can be formed to avoid the existence of vortex zones in the wind field of the settlements.

4.3 Mechanically Assisted Enhanced Ventilation Design

4.3.1 Enhanced ventilation for through-air ventilation

It is usually not customary to open windows on the back wall of some traditional dwellings in Lijiang area, which affects the indoor ventilation and air exchange effect to some extent. The strategy of opening holes for exhaust fans under the eaves of the dwellings is proposed. In order to strengthen the indoor ventilation effect, holes for exhaust fans can be opened under the eaves of the houses to create a through-the-air wind in the room. The fan in the hole position can assist in the formation of through-the-hall wind, and will not affect the facade of the building itself, nor will it cause damage to the facade of the building, thus preserving the historical style and cultural characteristics of the residence. If it is impossible to open holes in the wall due to structural reasons, it is recommended to set up a wind-pulling chimney on the roof to achieve the same ventilation effect. In order to realize the circulation and renewal of indoor air.

4.3.2 Stack Ventilation and Energy Utilization

In response to the situation that some traditional dwellings are unable to open holes in the wall due to the structural limitations of the wall, the mechanically assisted ventilation of chimneys in residential buildings is modified as shown in Figure 5. This design not only solves the ventilation problem, but also gives full consideration to energy utilization. The wind-pulling chimney can combine both solar energy and electric energy, using solar energy for natural exhaust in the case of sufficient sunshine, which is both environmentally friendly and economical. In case of insufficient sunshine, the chimney can be switched to mechanical exhaust mode to ensure that the indoor ventilation effect is not affected. This design takes into full consideration the historical value and cultural significance of the residential building, and also accomplishes the improvement of living comfort and the sustainable use of energy.

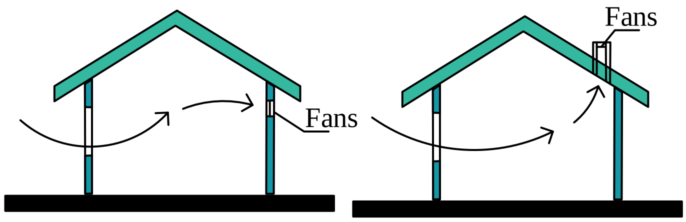
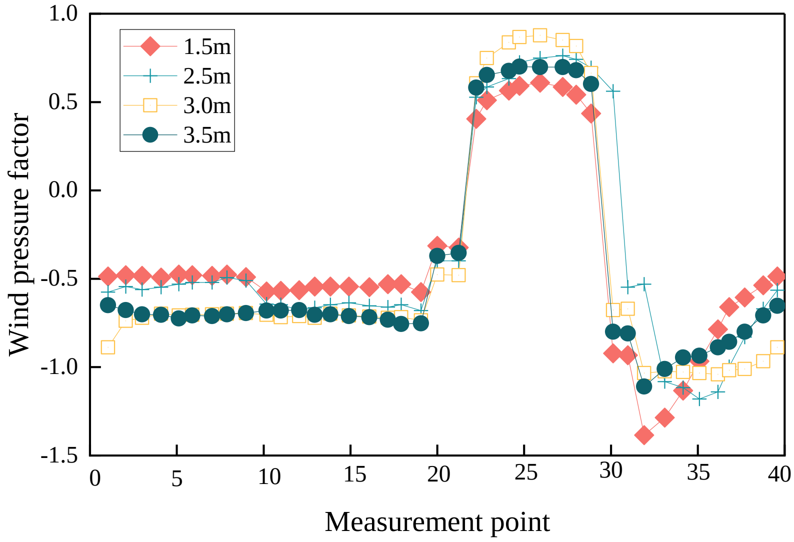


Figure 5 Mechanically assisted ventilation retrofit of chimneys in residential buildings

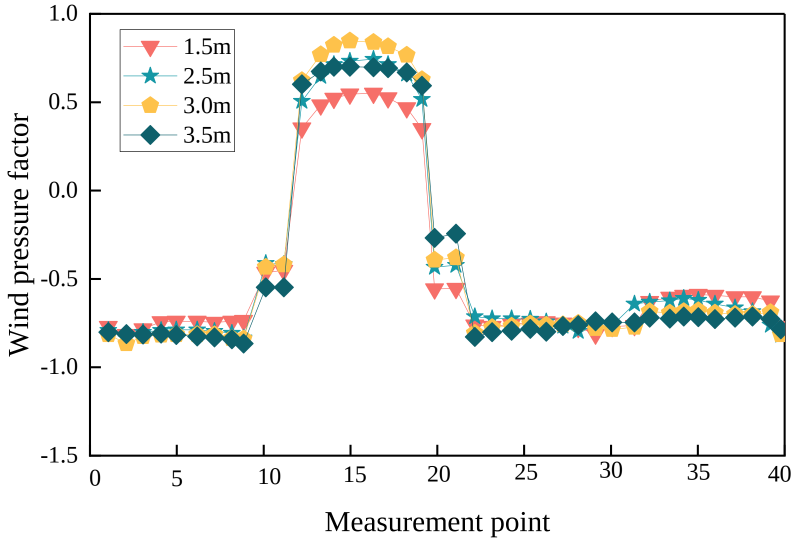
5. EVALUATION OF THE EFFECT OF WIND ENVIRONMENT ADJUSTMENT AND MODIFICATION

5.1 Wind pressure coefficients at different heights of the building for different wind angles

Traditional residential buildings have different wind environment characteristics due to their unique shapes and layouts. By dividing the experiment into two parts, it is possible to refine the study for the characteristics of each shape of building and reveal its wind environment characteristics more accurately. The wind pressure coefficient experiments at different heights were carried out, and round and square residential buildings were selected as research objects. By simulating the wind pressure coefficients of these two shapes of buildings at different heights, the change of wind pressure distribution with height can be visualized, and Fig. 6 shows the wind pressure coefficients at different heights of the buildings. Figure 6(a) shows a circular residential building, and it can be seen that the wind pressure coefficient reaches its maximum value at a height of about 3m. At the slit of the two buildings, between measurement points 29-40, the wind pressure coefficient reaches a minimum value of 1.5m-3.5m at the wind pressure coefficient, both between -0.55-1.47. This indicates that the wall at this location is subject to the largest value of negative pressure, the slit effect is obvious, the leeward side and the side of the building is subject to negative pressure. Figure 6(b) shows a square residential building with the wind pressure coefficient reaching its maximum value at a height of about 3m. Also at the slit of the building, between measurement points 29-40, the wind pressure coefficient is between -0.27 and 0.49, which also reaches the minimum value. The significant influence of slit effect on the wind field is revealed. The wind pressure coefficient reaches its maximum value at about 3m height for both circular and square residential buildings, and it reaches its minimum value at the slits of the buildings. This finding is of great significance for optimizing building layout and reducing wind damage.



(a) Round residential buildings



(b) Square residential building

Figure 6 Wind pressure coefficients at different heights of the building

5.2 Curve of wind speed ratio at measurement points under different wind angles

Due to the unique internal structure and layout of the day-shaped residential buildings, all day-shaped residential buildings contain inner halls, and the architectural form is different from that of round and square residential buildings. The simulation experiments of wind speed ratio under different wind direction angles are carried out for Rizhi-shaped residential buildings. Figure 7 shows the wind speed ratios of measurement points under different wind angles, and it can be analyzed that the wind speed ratios of each measurement point are all below 1.00. The maximum wind speed ratios of each measurement point under 0° and 180° wind angles are all below 0.50, and the wind speed ratios of the measurement points 26-44 in front of the ancestor hall are less than 0.50

under most of the wind angles, and only under the 60° wind angle. As the incoming flow is incident from the side of the main building and the upper part of the side building, a vortex is formed in front of the ancestral hall and then separated by the upper part of the low gate tower, the wind speed ratio is greater than 0.50, and the wind speed ratio of the measurement points 73-90 in the rear of the ancestral hall changes greatly with the different wind angles, and the change of the wind speed ratio of the measurement point 81 is the greatest, from 0.21 to 0.95. In a word, the wind speed of the inner field of the Rizhi shaped residential buildings is relatively low, and the wind speed of the height of the pedestrians in the Rizhi shaped residential buildings is relatively small, and the wind speed under each wind angle is lower than 0.50. Is relatively small, averaging 0.34 under each wind angle, and in order to improve this situation, the doorway is increased to create a penetrating wind. This recommendation is not only based on simulation results, but also takes into full consideration the comfort and pollutant dispersion needs in actual use.

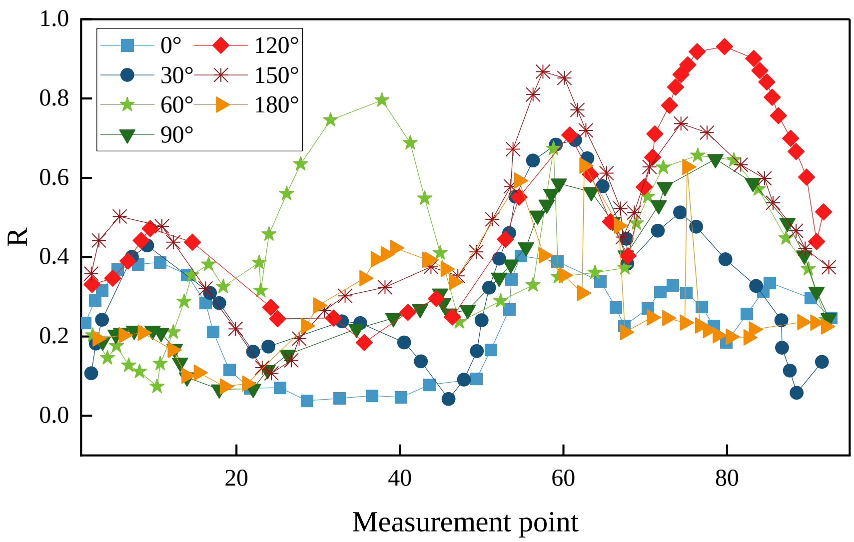


Figure 7 Ratio of wind speed at measurement points under different wind angles

5.3 Results of wind environment comfort assessment

Table 2 shows the wind environment comfort assessment of traditional residential buildings, which shows the effect of different residential building types on pedestrian activities during the warm and cold seasons. In the warm season, when R < 0.5, the measurement points outside the round, square, and day-shaped residential buildings all show lower percentages of 5.1%, 4.9%, and 4.4%, respectively. This indicates that the wind environment is relatively more comfortable in these areas, where pedestrians can perform outdoor standing and sitting activities for short periods of time without feeling strong wind. In particular, the number and percentage of R < 0.5 measurement points outside the day-shaped residential buildings were the lowest at 4.4%, suggesting that the wind environment around the day-shaped residential buildings may be more pleasant during the warm season. Therefore, the wind environment around residential buildings provides good outdoor conditions for pedestrians during the warm season. In the cold season, when R>1.5, the high percentage of measurement points outside the building reveals a stronger wind environment. The percentages of measured points outside the buildings of round, square and day-shaped residential buildings were 34.3%, 35.6% and 34.4%, respectively, which implies that pedestrians tend to walk fast to minimize the effects of cold and wind in these areas. Especially, square residential buildings have the highest number and percentage of measurement points with R>1.5 outside their buildings. This suggests that the wind environment around square residential buildings may cause greater discomfort to pedestrians during the cold season.

Table 2 Wind environment comfort assessment of conventional residential buildings

Types of residential buildings	**Location of measurement point**	**Number of points**	**R < 0.5**		**R > 1.5**		**R average**	**Rmax**
Round residential buildings	Outside	5176	265	5.1%	1774	34.3%	1.34	1.94
	Inside	2809	825	29.4%	0	0%	0.55	1.00
Square residential buildings	Outside	5176	252	4.9%	1842	35.6%	1.34	1.94
	Inside	2021	847	41.9%	0	0%	0.64	1.02
Day-shaped residential buildings	Outside	4500	200	4.4%	1550	34.4%	1.30	1.88
	Inside	2500	700	28.0%	0	0%	0.58	1.01

6. CONCLUSION

This paper provides a new way to adjust and optimize the wind environment of traditional residential buildings through computational geometry technology. Through accurate three-dimensional geometric modeling and advanced numerical simulation technology, the wind field distribution of traditional residential buildings under different wind conditions is comprehensively analyzed. The building models of circular residential buildings, square residential buildings and day-shaped residential buildings are established, the specific applications of model grid division and wind angle setting are introduced, and the principles and methods of selecting boundary conditions and turbulence models are elaborated in detail. The results are as follows:

(1) The wind pressure coefficient reaches the maximum value at about 3m height in both round and square residential buildings, and the wind pressure coefficient reaches the minimum value at the slit of the building. The wind speed in the inner field of the sun-shaped residential buildings is lower, and the wind speed at the height of the pedestrians inside the sun-shaped residential buildings is relatively small, with an average of 0.34 under each wind angle, aiming to comprehensively improve the quality of the wind environment and the living comfort of the traditional residential buildings.

(2) In the warm season, the measurement points outside the buildings of round, square and day-shaped residential buildings show lower percentages of 5.1%, 4.9% and 4.4%, respectively. In the cold season, the high percentages of the measurement points outside the building revealed a stronger wind environment.

(3) Strategies for protective retrofitting including design of the building exterior environment and ventilation, optimal design of the building structure to guide natural ventilation, and mechanically-assisted enhanced ventilation design were developed. The percentages of measured points outside the buildings of round, square and sun-shaped residential buildings are 34.3%, 35.6% and 34.4%, respectively, which are important for promoting the sustainable utilization and development of urban historical and cultural heritage.

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